Faculty of Information and Communication Technology

HYBRID ARTIFICIAL BEES COLONY ALGORITHMS FOR OPTIMIZING CARBON NANOTUBES CHARACTERISTICS

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DECLARATION

I declare that this thesis entitled “Hybrid Artificial Bees Colony Algorithms for Optimizing Carbon Nanotubes Characteristics” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

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Supervisor Name	:	Dr. ABDUL SYUKOR BIN MOHAMMAD JAYA
Date	:	.....

DEDICATION

To my beloved mother and father, may Allah's mercy and forgiveness be upon him, I miss him so much.

ABSTRACT

Optimization is a crucial process to select the best parameters in single and multi-objective problems for manufacturing process. However, it is difficult to find an optimization algorithm that obtain the global optimum for every optimization problem. Artificial Bees Colony (ABC) is a well-known swarm intelligence algorithm in solving optimization problems. It has noticeably shown better performance compared to the state-of-art algorithms. This study proposes a novel hybrid ABC algorithm with β-Hill Climbing (βHC) technique (ABC-βHC) in order to enhance the exploitation and exploration process of the ABC in optimizing carbon nanotubes (CNTs) characteristics. CNTs are widely used in electronic and mechanical products due to its fascinating material with extraordinary mechanical, thermal, physical and electrical properties. Chemical Vapor Deposition (CVD) is the most efficient method for CNTs production. However, using CVD method encounters crucial issues such as customization, time and cost. Therefore, Response Surface Methodology (RSM) is proposed for modeling and the ABC-βHC is proposed for optimization purpose to address such issues. The selected CNTs characteristics are CNTs yield and quality represented by the ratio of the relative intensity of the D and G-bands (ID/IG). Six case studies are generated from collected dataset including four cases of CNTs yield and one case of ID/IG as single objective optimization problems, while the sixth case represents multi-objective problem. The input parameters of each case are a subset from the set of input parameters including reaction temperature, duration, carbon dioxide flow rate, methane partial pressure, catalyst loading, polymer weight and catalyst weight. The models for the first three case studies were mentioned in the original work. RSM is proposed to develop polynomial models for the output responses in the other three cases and to identify significant process parameters and interactions that could affect the CNTs output responses. The developed models are validated using *t*-test, correlation and pattern matching. The predictive results have a good agreement with the actual experimental data. The models are used as objective functions in optimization techniques. For multi-objective optimization, this study proposes Desirability Function Approach (DFA) to be integrated with other proposed algorithms to form hybrid techniques namely RSM-DFA, ABC-DFA and ABC-βHC-DFA. The proposed algorithms and other selected well-known algorithms are evaluated and compared on their CNTs yield and quality. The optimization results reveal that ABC-βHC and ABC-βHC-DFA obtained significant results in terms of success rate, required time, iterations, and function evaluations number compared to other well-known algorithms. Significantly, the optimization results from this study are better than the results from the original work of the collected dataset.

ABSTRAK

Pengoptimuman adalah suatu proses yang penting bagi memilih parameter yang terbaik dalam masalah satu dan berbilang-objektif untuk proses pembuatan. Walau bagaimanapun, ia adalah sukar bagi menjumpai satu algoritma pengoptimuman yang mendapat optimum keseluruhan untuk setiap masalah pengoptimuman. Koloni Lebah Buatan (ABC) adalah algoritma kepintaran kawanan yang dikenali dalam menyelesaikan masalah pengoptimuman. Ia telah menunjukkan prestasi yang lebih baik berbanding dengan algoritma-algoritma terkini. Kajian ini mencadangkan algoritma baru hibrid ABC dengan teknik Pemanjatan Bukit-β (βHC) (ABC-βHC) untuk meningkatkan proses eksploitasi dan penerokaan ABC dalam pengoptimuman ciri-ciri Karbon nanotiub (CNTs). CNTs digunakan secara meluas pada produk elektronik dan mekanikal disebabkan oleh bahannya yang menarik dengan ciri-ciri mekanik, haba, fizikal dan elektrik yang luar biasa. Pemendapan Wap Kimia (CVD) adalah kaedah yang paling berkesan untuk penghasilan CNTs. Walau bagaimanapun, dengan menggunakan kaedah CVD, terdapat masalah penting seperti penyesuaian, masa, dan kos. Oleh sebab itu, Metodologi Respons Permukaan (RSM) dicadangkan untuk permodelan dan ABC-βHC dicadangkan untuk tujuan pengoptimuman bagi menangani isu-isu tersebut. Respon output yang dipilih adalah %hasil karbon dan kualiti CNT yang diwakili oleh nisbah keamatan relatif D dan G-band (ID / IG). Enam kajian kes dihasilkan daripada set data yang dikumpul termasuk empat kes %hasil karbon dan satu kes ID / IG sebagai masalah pengoptimuman tujuan tunggal, manakala kes keenam mewakili masalah berbilang-objektif. Parameter input setiap kes adalah subset dari set parameter input termasuk suhu tindak balas, tempoh, kadar aliran karbon dioksida, tekanan separa metana, pemuatan pemangkin, berat polimer dan berat pemangkin. Model ramalan bagi tiga kajian kes pertama disebut dalam karya asal. RSM dicadangkan untuk membangunkan model ramalan polinomial untuk respon output dalam tiga kes yang lain. Kemudian, parameter proses yang penting dan interaksi yang boleh menjejaskan tindak balas output CNT telah dikenalpasti. Model yang dibangunkan telah disahkan menggunakan ujian t, korelasi dan corak yang sepadan, dan keputusan ramalan mempunyai persetujuan yang baik dengan data eksperimen sebenar. Model tersebut digunakan sebagai fungsi objektif dalam teknik pengoptimuman. Untuk pengoptimuman berbilang-objektif, kajian ini mencadangkan Pendekatan Fungsi Keinginan (DFA) diintegrasi dengan algoritma lain yang dicadangkan bagi membentuk teknik hibrid iaitu RSM-DFA, ABC-DFA dan ABC-βHC-DFA. Algoritma yang dicadangkan dan algoritma terkenal lain yang dipilih telah dinilai dan dibandingkan dengan hasil dan kualiti CNT mereka. Hasil pengoptimuman menunjukkan bahawa ABC-βHC dan ABC-βHC-DFA memperoleh hasil yang signifikan dari segi kadar kejayaan, masa yang diperlukan, lelaran dan nombor penilaian fungsi berbanding dengan algoritma lain yang diketahui. Secara signifikan, keputusan-keputusan pengoptimuman dari kajian ini adalah lebih baik daripada keputusan-keputusan hasil kerja asal terhadap set data yang dikumpulkan.

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ABC	-	Artificial Bee Colony Algorithm
BA	-	Bat Algorithm
CNTs	-	Carbon Nanotubes
CVD	-	Chemical Vapor Deposition
dBA	-	direct BA
DFA	-	Desirability Function Approach
EAs	-	Evolutionary Algorithms
FEN	-	Function Evaluation Number
GAs	-	Genetic Algorithms
GRASP	-	Greedy Randomized Adaptive Search Procedure
HC	-	Hill Climbing
HS	-	Harmony Search
M_ET	-	Mean Execution Time
M_RI	-	Mean Required Iterations
PSO	-	Particle Swarm Optimization
PVD	-	Physical Vapor Deposition
RSM	-	Response Surface Methodology
SR	-	Success Rate
TS	-	Tabu Search